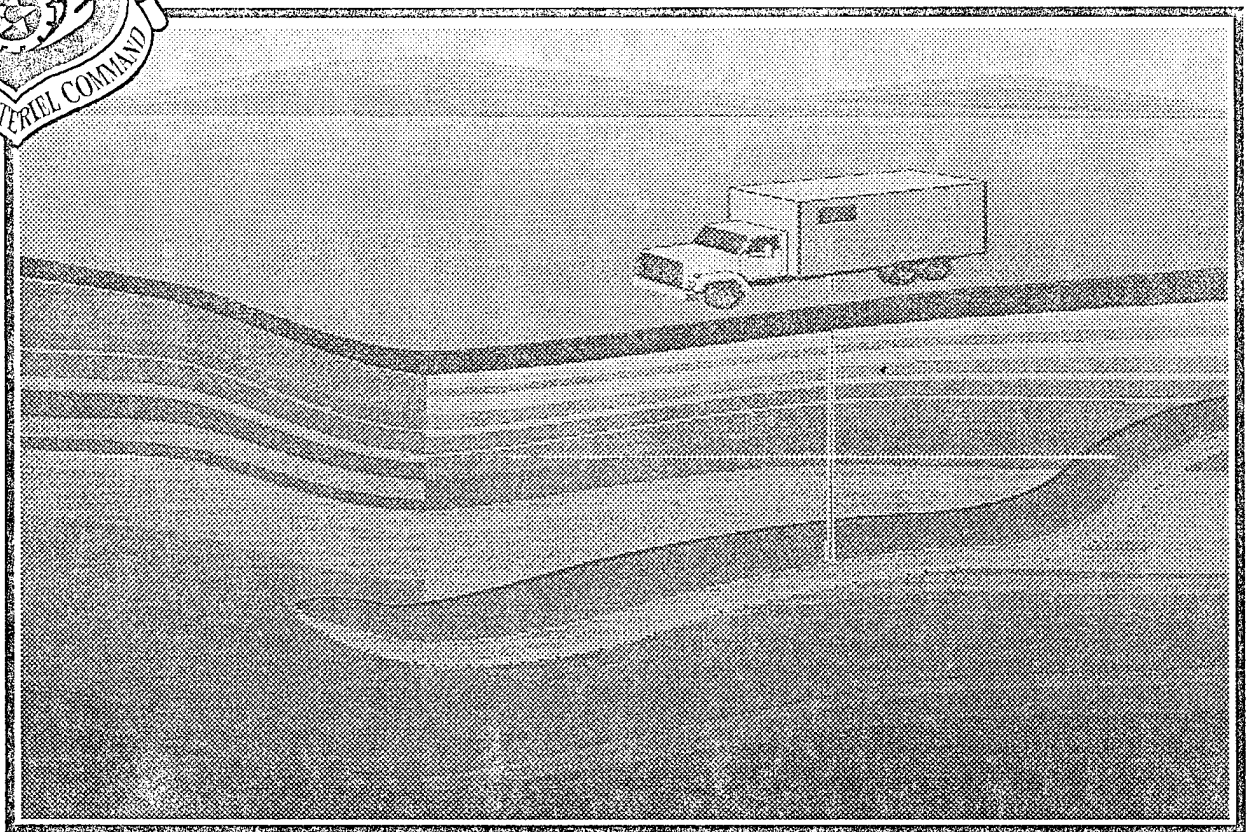
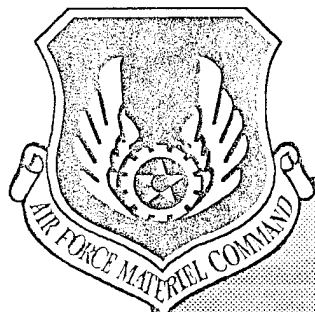


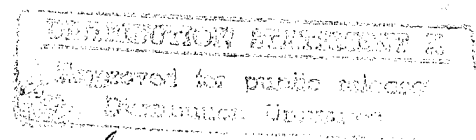
FY 96

CIVIL ENGINEERING & ENVIRONMENTAL QUALITY TECHNOLOGY AREA PLAN



HEADQUARTERS AIR FORCE MATERIEL COMMAND
DIRECTORATE OF SCIENCE & TECHNOLOGY
WRIGHT-PATTERSON AFB OH

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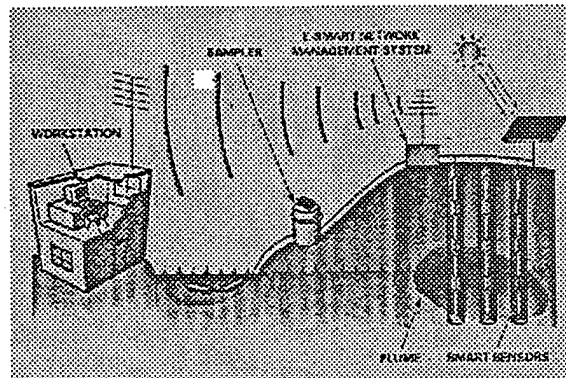
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Note: This Technology Area Plan (TAP) is a planning document for the FY96-00 S&T program and is based on the President's FY96 Budget Request. It does not reflect the impact of the FY96 Congressional appropriations and FY96-00 budget actions. You should consult AL/XP for specific impacts that the FY96 appropriation may have had with regard to the contents of this particular TAP. This document is current as of 1 May 1995.

CIVIL ENGINEERING AND ENVIRONMENTAL QUALITY



VISIONS AND OPPORTUNITIES

Air Force installations, whether operating on foreign or home soil, will continue to face many problems requiring innovative solutions in the Civil Engineering & Environmental Quality Technology research & development (R&D) areas. These bases must be able to defend against attack, survive, recover, and support aircraft sortie generation following an attack; i.e., be able to sustain reliable airfield operations for all types of airborne weapon systems during wartime. Environmental technologies apply to war and peace operations in a highly sophisticated world. International politics demand environmental cleanup even after hostile engagements; and in peacetime, we must comply with the world trade agreements and the ever-increasing stringency of environmental laws and regulations by mitigating the environmental impact of weapon systems, and providing cost-effective cleanup and site remediation of hazardous waste. Reduced budgets, combined with increased environmental regulatory pressure, dictate smarter, more economical and faster cleanup technologies, reduced generation of hazardous wastes, and increased recovery and recycling of materials. Base realignment and closure actions place an added urgency on bringing sites into compliance. The development endeavors of this technology area face these challenges head on.

Understanding, predicting, and controlling Air Force air pollutant emissions is critical to

continued, efficient training and operations. The FY90 Clean Air Act Amendments regulate the release of smog and ozone precursors, climatic change agents, and air toxic compounds. We must understand the behavior and fate of Air Force atmospheric pollutants and reduce them wherever possible, in order to avoid adverse actions which could impede mission accomplishment. Waste treatment technologies designed for Air Force-unique waste streams, that treat wastes before they are mixed or diluted, offer opportunities for generators of wastes to be part of the solution to reduce hazardous wastes.

We are aggressively addressing base cleanup requirements by developing the most advanced and innovative technologies possible. Of the Air Force's approximately 5000 contaminated sites, innovative site remediation technologies will help locate, characterize, and remediate over 2800 sites contaminated with fuels and solvents. Much of this technology will also be applied to DOD's remaining 15,000 plus sites. Our vision is to develop real-time capabilities using modern computer-aided systems and fiber optics. Optimum use of natural, in-place processes will greatly reduce costs associated with conventional technologies. Technology development in progress addresses newly developed and future chemicals, materials, and processes in Air Force operations, as well as remediation of past problems. Technology demonstrations of new organisms to degrade

previously "undegradable" materials, novel sensors for *in situ* characterization, *in situ* cleanup methods, and toxic waste minimization for the Air Force and DOD will reduce the overall cost of ownership.

Energy and utilities assume life or death importance to operations during wartime. Development of compact, lightweight, highly efficient, combat-durable energy technologies is essential to meet the requirement for stand-alone air-mobile systems. These mobile utility systems are indispensable for support of critical electronic equipment, mobile command centers, computer facilities, and mobile collective protection facilities associated with bare bases. Global Reach dictates rapid transition from bare base to full combat-capable status using minimum airlift resources.

Worldwide instability mandates worldwide air operations on extremely short notice. Our forces must assess runway pavement conditions and sortie-generation capability within a matter of hours. We are developing innovative nondestructive testing and evaluation techniques and advanced methods of rapidly upgrading contingency airfields to meet this need. To ensure sustained air operations, we are developing new pavement repair techniques using advanced slurry formulations and other synthetic materials.

Air mobility, flexibility, rapid constructability, and weapons effects protection continue to be the key to future airbase structures in meeting global contingencies. The Air Force might exploit a worldwide system of airfields adequate for high-performance aircraft through the development of rapidly erectable airmobile or pre-positioned modular structures to make those airfields functional in a combat environment. Multiple-delivery modes for munitions require that

key airbase structures provide weapons effects protection, particularly against tactical ballistic missiles with area-coverage warheads. In concert with our weapons effects program, we are developing design concepts for structures to defeat these weapons.

Firefighting is being revolutionized by increasing environmental concerns. Front-line fire-extinguishing agents cause environmental problems. Similarly, firefighter training with hydrocarbon fires has been severely restricted. Development focus is on environmentally acceptable agents to replace ozone-depleting halons and aqueous film-forming foams, which have limited biodegradability. We will use "Virtual Reality" technology for development of training systems to simulate fire, crash, and rescue. Composite materials degrade rapidly and generate hazardous particles when exposed to fire. This requires development of faster, more reliable fire detection/suppression and hazardous materials containment/decontamination procedures.

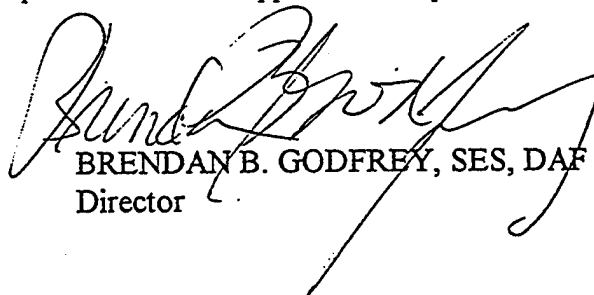
Evolving technologies provide the opportunity to develop more capable heat and chemical resistant clothing, coupled with space age body-cooling technology.

Our vision recognizes the need for a combination of new and existing technologies to increase our dual role as a leading contributor to airbase survivability and as a major participant in DOD's efforts to preserve and improve environmental quality. Many of these technologies are dual-use and are transferred to non-Federal entities through our technology transfer programs, as appropriate, and are a result of extensive cooperation and collaboration with Air Force, DOD, other government partners, industry, and academia.

This plan has been reviewed by all Air Force laboratory commanders/directors and reflects integrated Air Force technology planning. I request Air Force Acquisition Executive approval of the plan.



RICHARD R. PAUL
Brigadier General, USAF
Technology Executive Officer



BRENDAN B. GODFREY, SES, DAF
Director

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INTRODUCTION

BACKGROUND

The Civil Engineering (CE) and Environmental Quality (EQ) Technology Area's mission is to lead the Air Force in conducting CE & EQ technology development that sustains Air Force wartime and peacetime operations. The Wright Laboratory Airbase Systems Branch, Flight Dynamics Directorate (WL/FIVC) conducts civil engineering research; the Armstrong Laboratory Envirionics Directorate (AL/EQ) conducts environmental quality research. However, Armstrong Laboratory has overall responsibility for publication of the CE and EQ Technology Area Plan (TAP). Figure 1 shows the relationship of this TAP to the overall Air Force Science and Technology (S&T) program, along with the Program Element funding sources.

The CE & EQ Technology Area provides technologies fundamental to the operation, maintenance, survivability, and post attack recoverability of airbases. This includes the environmental treatment technologies necessary for hazardous waste cleanup and process controls for routine operation and maintenance of airbases throughout the world. Figure 2 shows that the CE & EQ S&T funding is approximately 2 percent of the entire Air Force S&T program funding.

The Air Force flying mission depends on the reliability and sustainability of ground-based support systems. Increased reliance on sophisticated electronic and computer-based systems dictates the development of fail-safe utility technologies. Recent technology breakthroughs in power generation and control, coupled with application of superconductivity, facilitate laboratory development of miniaturized power generation systems. The concept of global deployment mandates that utility systems be able to stand alone and use a variety of fuels. To address this requirement, our scientists are developing interface systems to allow use of available theater fuels.

Pavement integrity is essential to the flying mission during peacetime and critical to sortie generation in wartime. Our scientists are developing advanced pavement evaluation technologies that can provide total assessment of an airfield in hours, as compared to days with current systems. Deployment to remote airfields around the world is critical to supporting the strategy of Global Reach-Global Power. Advanced materials and soil stabilization techniques now being developed will create operating surfaces capable of supporting all airlift requirements.

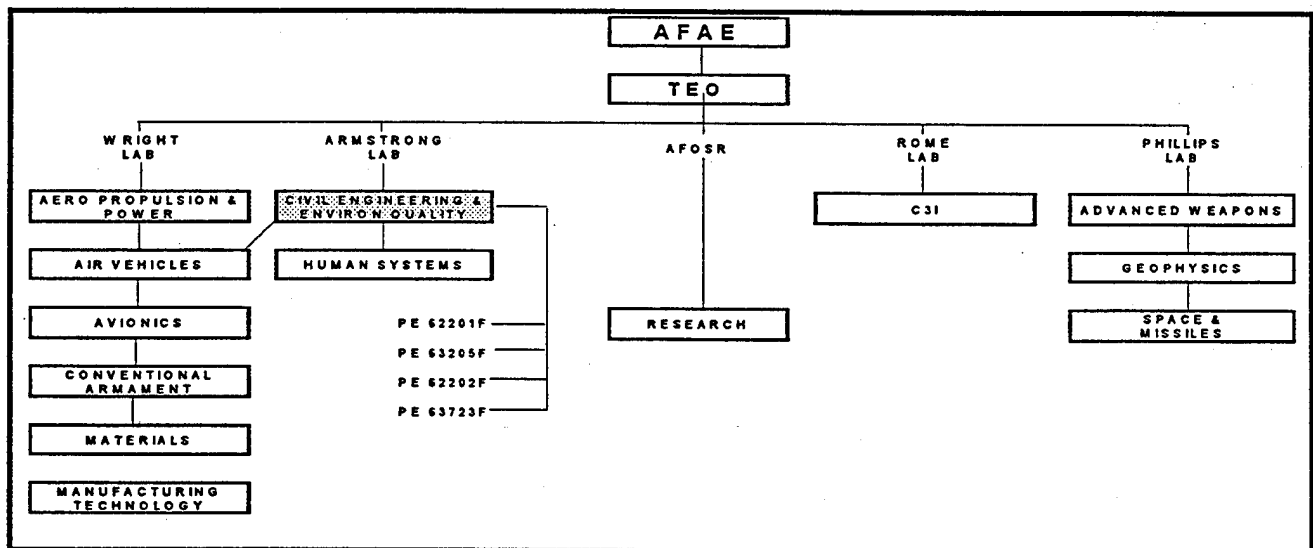


Figure 1. Air Force Science & Technology Structure

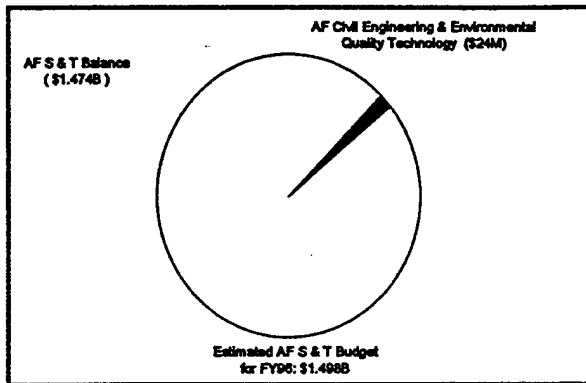


Figure 2. Civil Engineering & Environmental Quality S&T Vs AF S&T Funding

The challenge of the Air Force's increased involvement in space lift operations necessitates new firefighting strategies. Advanced firefighting agents and equipment now being developed will help to protect these vital national assets.

Environmental Quality technology supports the Air Force mission by reducing the cost of cleaning up past contaminated sites, while assuring environmental compliance necessary to sustain peacetime training, operations and maintenance missions. Increasing regulatory restrictions on air and water quality challenge this technology area to identify and cost effectively abate adverse environmental impacts without degrading mission capability. Recent accomplishments include an Eielson AFB, AK, field demonstration of *in situ* bioremediation of fuel- and solvent-contaminated soil under sub-arctic conditions. This technology has already been transitioned for tests at over 130 arctic sites with millions of dollars in savings to the Air Force in site cleanup costs. AL/EQ developed tunable laser spectrometer technology, integrated with a cone penetrometer used to characterize a fuel-contaminated site at Plattsburgh AFB, NY. We are characterizing additional Air Force installations to determine the feasibility of natural attenuation. This provides more efficient and timely information which may be used in deciding to use the natural attenuation option, saving the Air Force millions of dollars in site cleanup costs.

The CE & EQ Technology Area is divided into four major thrusts, as shown in Figure 3. The first two concentrate on developing technologies to provide the Air Force infrastructure support

necessary to project aerospace power. The last two thrusts focus on hazardous waste minimization and air pollution control for maintaining compliance with environmental laws, and remediation technologies for costs savings in site cleanup, now and in the future.

MAJOR TECHNOLOGY THRUSTS

1. Airbase Infrastructure
2. Airbase Pavements & Facilities
3. Environmental Compliance
4. Site Remediation

Figure 3. Major Technology Thrusts

The distribution of Air Force S&T funds among these thrusts is shown in Figure 4. Funding figures reflect the FY 96 President's Budget Request.

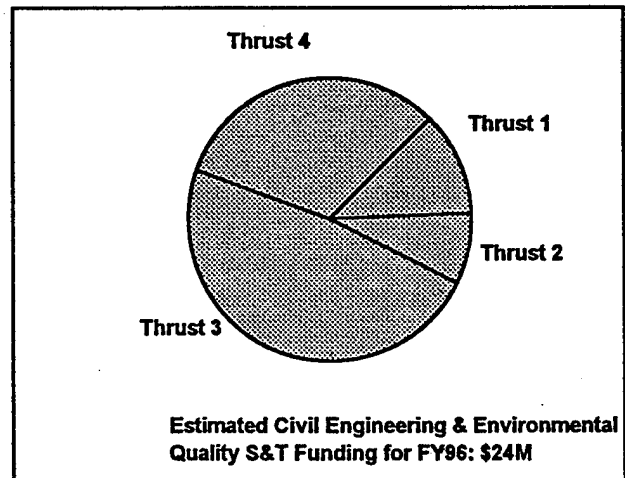


Figure 4. Actual Funding By Major Technology Thrust

RELATIONSHIP TO OTHER TECHNOLOGY PROGRAMS

The CE & EQ TAP is closely coordinated with other Air Force S&T programs and other DOD laboratory programs. The Tri-Service Project Reliance Civil Engineering S&T Plan and the Tri-Service Environmental Quality R&D Strategic Plan reflects CE and EQ efforts to establish integrated, effective programs. Steps taken through Project Reliance and other means ensure there is no

duplication of effort. Wherever possible, Air Force S&T programs are leveraged with industry and international efforts to realize the largest payoff to the Air Force.

AL/EQ and WL/FIVC are members of a regional (Northwest Florida and Southern Alabama) technology transfer organization called the Gulf Coast Alliance for Technology Transfer (GCATT). GCATT is comprised of 11 federal laboratories, four universities, and a consortium of community colleges. The goal of this organization is to link government technology and test facility assets to meet industry needs.

Four Data Exchange Agreements (DEAs), one Information Exchange Agreement (IEA), and one Memorandum of Understanding (MOU) are in effect for this Technology Area.

Armstrong Laboratory (AL) and Wright Laboratory (WL) collaborate in several programs to minimize environmental impacts of many Air Force operations and industrial processes. These efforts include (1) reducing hazardous wastes generated in painting and paint-stripping operations, (2) characterizing hazardous air pollutants (HAPs) from the combustion of JP-8 in aircraft turbine engines, auxiliary power units and aerospace ground equipment (AGE), (3) the development of alternate processes to replace electroplating such as spray casting and ion vapor deposition (IVD) of heavy metals, and (4) the recovery, treatment, and recertification of aviation hydraulic fluids.

AL/EQ provided the lead in establishing with Space and Missile Center, Phillips Laboratory, the East and West Missile Test Ranges, and the Army Research Lab at White Sands a fully coordinated, integrated program to address critical deficiencies in the transport and diffusion models for space launch operations. These deficiencies directly resulted in recent launch aborts. Efforts in this area include the development and incorporation of chemical reactivity data and the refinement and validation of current models through large-scale tests employing state-of-the-art monitoring technology.

Through leveraging the Joint Ordnance Commanders Group (JOCG) sponsored Large Rocket Motor Demil/Disposal program, and coordinating with HSC/YAQ and the Silo-Based ICBM SPO, a program has been developed to provide environmentally sound alternatives for

propellant removal and case recovery/reuse for the Minutemen ICBM life extension program.

The Small Business Innovation Research (SBIR) program supports a number of research efforts in this Technology Area. Eleven new awards were made for environmental quality and four for civil engineering in FY94, and we anticipate about the same number in FY95. The research includes industrial waste treatment, air and water pollution control, and remediation technology in the areas of bioremediation and physical/chemical treatment. Phase I SBIRs have been focused to address specific Air Force needs in the areas of oil/water/emulsion treatment, metals removal from industrial waste water and novel reaction/reactor technologies to treat specific aqueous and gaseous effluents. Some very successful efforts have been continued into phase II. One program looks at ways to produce an environmentally compatible aircraft/runway deicer and fuel system ice inhibitor in collaboration with WL, Naval Research Laboratory (NRL), and the Air Force Civil Engineering Support Agency (AFCEA). Another program, coordinated with the Army, looks at treatment of soils contaminated by mercury or depleted uranium by supercritical fluid extraction. Other projects will demonstrate a transportable treatment system for the removal of aqueous film forming foam (AFFF) from hanger deluge or firefighting waste water, develop and demonstrate catalytic treatment processes for the removal of NOx and VOCs from jet engine test cells, other combustion sources and corrosion protection facilities, and to develop tools to better characterize and predict rocket plume dispersion.

The Strategic Environmental Research and Development Program (SERDP), as mandated by law, addresses environmental matters of concern to the DoD and DOE. It is conducted as a tri-agency program with participation from the DoD, DOE, and EPA. AL/EQ manages the Air Force portion of the DoD/National Environmental Technology Demonstration Program (D/NETDP) funded by SERDP. SERDP funding for AL/EQ is approximately \$5 million in FY96, for research in the area of cleanup and compliance, and is approximately \$2 million for WL/FIVC, for research in the area of pollution prevention and energy conservation.

Every odd numbered year, WL/FIVCS and a major NATO country co-sponsor an International

Symposium on the Interaction of Nonnuclear Munitions With Structures. This symposium, with the involvement of the attending countries, produces a comprehensive review of major research and development efforts and technology development. This ensures that the most important areas are developed, duplication is minimized, all possible future conflict scenarios are reviewed, and the most critical needs are covered in a technology plan.

Project Reliance results in fully integrated tri-service technology development in the CE & EQ Technology Area. Joint programs exist for *in situ* sensor development, installation restoration, and deicer/ice inhibitors. We have established reliance on the Army Corps of Engineers Waterways Experiment Station (WES) for material characterization, selected large-scale laboratory tests, and modeling.

The Project Reliance category of Critical Airbase Facilities/Recovery provides the framework for continued technology development in areas unique to the Air Force's need for force projection and beddown capabilities and for its requirement to recover bases after attack. Under this area, WL/FIVC has the lead for development of mobile protective shelters, utilities and energy systems. Project Reliance formalized airfield pavements and rapid runway repair for all services, with one reporting document. Rapid Airfield Stabilization, a joint effort with WES, is continuing. This effort will produce new materials and designs for quickly applying mechanical means to improve *in situ* soil strength.

WL/FIVC (Tyndall AFB, FL) conducts technology development on replacement agents for Halon 1301, used in critical facilities, aircraft cargo bays, and aircraft simulators, and Halon 1211, used in flightline and aircraft hand-held fire extinguishers. WL/FIVS (Wright-Patterson AFB, OH) conducts technology development on replacement agents for Halon 1301 used as a fire-explosion suppressant in aircraft engine nacelles and dry bays. Although the Halon 1301 applications are similar, due to space and weight constraints and engine airflow characteristics, these aircraft areas require a separate development effort. Conversely, the facility/cargo bay/simulator applications are constrained by toxicity considerations, because many facilities protected by Halon 1301 systems are occupied, as are cargo bays and simulators. Because the basic characteristics of fire suppression mechanisms are the same, two research efforts must be closely coordinated to avoid

duplication of effort and to utilize pertinent results from each effort as they evolve. Coordination is being accomplished through periodic visits, telephone communications, and exchange of technical reports.

AL/EQ has been designated as the lead laboratory for the fuels and solvents portion of the Installation Restoration subarea of Environmental Quality technology development under Project Reliance. This continues to be one of the major subthrusters in Site Remediation. Project Reliance pillar chairs recently met to update the Project Reliance Tri-Service Strategic Plan based on user capability needs and a fully integrated program. The deicer/ice inhibitors program mentioned earlier is an example of a technology being developed under Project Reliance to produce two products, one capitalizing on the other, while eliminating duplication of effort. Another technology is an airbase emission reduction planning model which will produce one product for both the Air Force and Army, eliminating duplication.

AL/EQ field demonstrations are partially supported by the Defense Environmental Restoration Account (DERA). Products transition to the Air Force Center for Environmental Excellence (AFCEE) to get the innovative technology to the field quickly, or to HSC/YAQ for 6.4 Engineering and Manufacturing Development. AL/EQ, a center of biotechnology development, leads in the use of bacteria and enzymes to clean up sites and dispose of waste.

Basic research (6.1) funded by AFOSR is an important feed for much of the exploratory development in this technology area. Biodegradation technologies, sensor development, solvent and contaminant fate and transport, and innovative pavement repair and performance prediction are all current AFOSR funded programs.

CHANGES FROM LAST YEAR

In October FY94, the Wright Laboratory Air Base Systems Branch reorganized to accommodate the effects of downsizing and budget restrictions. The TAP has been refocused to better reflect user priorities and is based on needs prioritized by the Air Force Civil Engineering community and Air Staff. The three thrust areas contained in the FY95 TAP (Airbase Operability & Repair, Airbase Survivability, and Fire Protection & Crash Rescue)

have been consolidated into two thrust areas for FY96 and the funding for civil engineering research has been placed under PE0602201F, Project 4397, and PE0603205F, Project 4398. Both projects are entitled "Air Base Technology" and fall under PE's within the Flight Dynamics Directorate at Wright Laboratory, Wright Patterson AFB OH, to better accommodate fiscal management within the directorate's chain-of-command.

In March FY93, the Air Force Materiel Command Commander (AFMC/CC) directed the Center Technology Councils to identify all AFMC environmental technology needs as the first application of the Technology Master Process. As a result, over 180 needs were identified, evaluated and prioritized. Those requiring technology development were sent to the laboratories to use in developing their programs. HSC/DRE (then HSC/XRE), the Environment, Safety, and Occupational Health (ESOH) Technical Planning Integrated Product Team (TPIPT) expanded the needs process to include other major commands. The FY94 ESOH Technology Needs Survey conducted by HSC/DRE was much more comprehensive across the major commands and included much more technical detail about the

individual needs. Over 300 needs were identified and several meetings of the TPIPT held to review, consolidate, and prioritize the needs. Similar needs were grouped into "super needs" with a resulting total of over 160 needs. The laboratories have been involved throughout the process to assist in identifying and documenting the needs, provide technical input into the prioritization process, assist in identifying those needs requiring technology development, and to develop programs to satisfy those needs. These needs and programs form the basis of the Air Force Environmental Quality Research, Development & Acquisition Strategic Plan. Based on this process and the improved needs survey, the environmental quality portion of this technology area plan has been revised in several areas to more specifically address the customers' highest priority needs.

Several funding adjustments (both increases and decreases) have occurred in the past year and are projected for FY96. The most significant was a significant increase in both the 6.2 and 6.3 funding for environmental quality. This increase was in response to the documented shortfall in funding required to address the user needs.

THRUST 1: AIRBASE INFRASTRUCTURE

USER NEEDS

The following user needs have been identified in Mission Need Statements (MNS), Statements of Need (SON), Operational Requirement Documents (ORDs), and DoD Energy Policy Directive (EPD) documents

- **Air Force Bare Base Systems:** The Air Force needs an integrated, expanded, and enhanced bare base systems capability to facilitate and support contingency operations, force projection efforts, and air combat operations.
- **Sustainable Air Base Utility Systems (SABUS):** A critical requirement exists for rapid repair kits, increased sustainability, and improved damage assessment capabilities to operate airbase utility systems for both peacetime and wartime operations.
- **Bare Base/Backup Power Systems:** The bare base power system is required during expedient construction and operation of airbase facilities for contingency force beddown and expedient post attack recovery of vital airbase facilities, whereas the backup power system is used primarily during commercial power outages.
- **New Family of Environmental Control Units:** A new family of environmental control units is required to provide heating, ventilation, and air-conditioning support to existing and next-generation air-portable bare base shelters.
- **Energy Usage Reduction in DOD Installations:** Reduce facility energy consumption 20 percent by the year FY00 and boost industrial energy efficiency by 20% between 1985 and FY00.
- **New Generation of Firefighting and Crash Rescue Systems:** Identifies needs for improved firefighting systems in the areas of (1) command, control, and communications; (2) environmentally safe fire-suppression agents; (3) fire detection, control, and suppression systems; (4) firefighting vehicle and associated equipment packages; (5) firefighter life support systems; (6) training; (7) protective clothing; (8) specialized

rescue equipment; and (9) self-contained breathing apparatus (SCBA).

- **Replacement of Halogenated Fire Extinguishing Agent:** Identifies a need to find a replacement agent for Halon 1301 used in current fire suppression systems that protect vital computer systems and electronic equipment in command and control facilities.

GOALS

To support the stated user needs, the following goals have been established:

- Develop mobile energy/utility technologies for force projection,
- Construction of lightweight, non-chlorofluorocarbon-using environmental control units for bare base shelters,
- Provide innovative solutions to reduce energy and utility systems O & M costs,
- Development of effective, safe firefighting agents to replace environmentally harmful chemicals,
- Development of improved fire detection and suppression technologies to enhance protection of critical Air Force assets, and
- More realistic, cost effective fire threat assessment and firefighter training.

MAJOR ACCOMPLISHMENTS

Major accomplishments in energy technology include fabrication of a lightweight generator that can revolutionize mobile power. This generator utilizes recent advances in rotary engine technology, high performance permanent magnet electrical energy conversion, and high speed switching. These technologies make it possible to reduce the weight of the next generation system by 30 percent and volume by 40 percent. This technology will undergo continued development and testing at the energy laboratory. This initial system will lead to development of a modular approach in a family of generators which use common components for a wide range of power capabilities.

AIR BASE INFRASTRUCTURE

Subthrust	FY95	FY96	FY97	FY98	FY99	FY00	FY01	FY02+
Energy Technology	Lightweight/Backup Electric Power Systems							
	Mobile Utilities							
	Operable Utilities							
	Advanced Energy Systems							
Firefighting	Environmentally Safe Firefighting Agents							
	Advanced Fire Suppressant Technologies							
	Firefighter Protection Upgrades							
	Enhanced Fire Detection/Suppression Technology							
	Advanced Training Systems							

This reduces logistical demands for spares and minimizes training required for servicing units. The new generator will meet user needs for improved air transportability, reduce logistics requirements, enhance survivability, and simplify maintenance.

An equipment fragility test facility was constructed, and the first phase of equipment testing has been completed. The facility demonstrated the capability of simulating ground shock of conventional weapons effects on full scale test articles used in typical HVAC systems. The units tested demonstrated that current design methodology is significantly more conservative than expected, and that use of expensive shock isolation may be reduced. Continued testing will provide the statistical data base required for improvements in the design criteria for facility equipment. This will lead to improved equipment survivability and reduced construction cost.

An environmentally acceptable method of disposal of waste fuels by burning them in the traditional boilers was tested in our boiler and fuel research facility. Preliminary test results with four blends of used POLs and diesel fuels indicated a potential of savings in millions of dollars in disposal and fuel costs. Testing will continue with various mixtures of waste POLs with virgin fuels to determine full environmental and operational impacts.

Several significant development efforts were completed that will result in improvements in environmental impact of current DOD firefighting agents. A highly successful blend of solvents was developed to replace butyl corbitol, a toxic component of Aqueous Film Forming Foams (AFFF), the Air Force's primary firefighting agent for fuel/oil fires. Revision of the AFFF specification has been initiated. Investigations conducted under the Halon replacement project identified the fluoriodocarbon compound, CF₃I, as an effective and environmentally safe Halon 1301 replacement for use in unoccupied spaces and as a replacement for Halon 1211 used in portable fire extinguishers. The EPA has since approved this chemical for these applications through their Significant New Alternatives Program.

Fabricated prototypes of firefighting/ hazardous materials ensemble garments using advanced heat resistant and toxic chemicals resistant materials. These garments will permit firefighting operations in intense heat up to 3000°F and/or in extremely

hazardous environments. The garments will be integrated with the newly developed cryogenic breathing air/body cooling system (reported in the FY95 TAP) to produce a prototype Firefighting/Hazmat Ensemble which will provide firefighters with greatly enhanced capabilities.

Developed an advanced propane firefighter training system. Major enhancements include (1) redesigned pool fire burners and increased liquid propane flow to provide larger, more realistic pooled fuel fires and (2) redesigned engine nacelle burners to produce a more uniform flame that realistically simulates three dimensional fires that are experienced in flowing fuel fire scenarios. The enhancements were included in a design guidance manual and provided to AFCESA for distribution to field activities. These enhancements will dramatically increase effectiveness of firefighter training in the Air Force.

CHANGES FROM LAST YEAR

As a result of reorganization, this Thrust 1, Airbase Infrastructure, replaces FY95 Thrust 1, Airbase Operability and Repair, and Thrust 3, Fire Protection and Crash Rescue. Specifically, the Energy Subthrust from Thrust 1 and all the Thrust 3 Subthrusts were combined in this Thrust which now consists of two Subthrusts, Energy Technology and Firefighting. The Operating Surfaces Subthrust from the Airbase Operability and Repair Thrust was combined with the FY95 Thrust 2, Airbase Survivability, into a new Thrust 2, Airbase Pavements and Facilities. The Automation Subthrust was deleted due to cancellation of automation requirements.

MILESTONES

Mobile energy and utility systems requirements for bare base applications will be met by FY00 through several lightweight power generation and distribution system projects. A Lightweight Power Generator will be developed by FY97, which will reduce the volume and weight of power generators by 30%, increase efficiency by 15%, and maximize survivability. A mobile heat pump unit using non-ozone-depleting refrigerants for bare base shelters will be developed by FY97. New innovative technologies such as superconductivity, solid oxide

fuel cells, and electromagnetic energy conversion will be utilized to develop the next generation of deployable power generation systems by FY00. These innovative technologies will improve equipment efficiency by 20%, reduce weight and volume by 40%, and cut O & M costs by 30%.

Energy efficiency technologies for airbase use at both fixed and bare base facilities will be developed by FY02. These technologies will reduce facility energy consumption and cost as well as meeting future weapon systems and facilities energy needs. These objectives can be fulfilled through several R&D efforts of emerging technologies in material advances, heat transfer fluid improvements, and alternate fuel technology which improve energy conversion performance, size, and efficiency.

Technology development to identify an environmentally friendly replacement for nonbiodegradable AFFF used in firefighting vehicles and facility fire suppression systems has been initiated (Concept Development - FY96; Validation - FY99). The program to replace ozone depleting Halon 1301 use in critical computer/electronic facilities has entered validation testing to select the

best of several candidate replacement agents. In association with this effort, a new aerosol fire suppression technology now under investigation shows strong promise to provide a new class of powerful flooding-type fire extinguishants (FY96). Technology development to find an ozone-and-global-warming-friendly replacement agent for Halon 1211 is now focusing on chemistries that are experimental in nature and exist only in laboratory quantities. Initial research is concentrating on several promising classes of chemical compounds which were previously identified (Concept Development - FY95; Validation - FY98).

Equipment enhancements include a new firefighting ensemble for hazardous material/high-temperature environments (Validation - FY96); advanced training technologies (Validation - FY97-FY99). Improvements in fire threat assessments and training are marked by completion of a firefighting and response model to the space lift facilities firefighting environment (FY95) and the beginning of a comprehensive effort to effectively fight large frame aircraft fires (FY95-FY96).

THRUST 2: AIRBASE PAVEMENTS AND FACILITIES

USER NEEDS

The Air Force new warfare doctrine based on Global Reach-Global Power requires new, rapidly deployable pavement and facility systems. User needs have been identified in the following Functional Area Plan (FAP), Mission Area Plans (MAP), and Mission Need Statements (MNS).

- **The CE Functional Area Plan:** This plan was formulated by an Air Base Systems Working Group consisting of representatives of all MAJCOM engineers. From this workshop, needs for portable pavement evaluation technologies for fixed and contingency basing, transportable matting for aircraft parking, rapid pavement creation techniques and advanced pavement repair materials and methods were identified. New portable shelter technologies, hardening using in-theater materials, lightweight composite materials, and methods to construct shelters from in-theater materials were additional requirements, all focusing on support of the mobility mission.
- **CAF 316-92 MNS Air Force Bare Base Systems:** Formalizes requirements for new systems to provide packages for housekeeping, flightline, and industrial support sufficient for 1100 people and one aircraft squadron equivalent. Systems must be robust, lightweight, operable in all climates, easily reconstituted, require no additional manpower, and operable in a chemical/biological environment.
- **CAF 305-92 MNS Camouflage, Concealment, and Deception (CCD):** Calls for new materials, techniques, and methods to reduce vulnerability of critical assets at both fixed and contingency sites.
- **AMC's Mobility Mission Area Plan (AMC-MP):** Defines deficiencies for facilities and infrastructure to support bare base operations.
- **ACC'S Air Base Systems Mission Area Plan (ACC-AD):** Defines a need for new deployable shelters with protection from conventional and chemical/biological threats; deployable defensive fighting positions;

munitions storage capability; airfield evaluation, construction, and repair techniques; and unsurfaced aircraft parking and taxi areas. Additional needs identified include camouflage and concealment technologies and rapid damage assessment and recovery methods.

GOALS

Based on user needs and requirements, the Pavements and Facilities Thrust is focused on providing new technology for rapidly constructable airbase infrastructure by the year FY00. This thrust will:

- Provide new pavement evaluation tools for fixed and bare base operations.
- Develop in-theater aircraft operating surface creation and repair methods.
- Develop new transportable shelters and chemical/biological processing for bare bases.
- Develop pavement database management tools and designs for superheavy transports.
- Develop new pavement materials and advanced composite material applications for contingency operations.
- Develop on-site expedient hardening, underground POL and munitions storage methods, and methodologies for bare base applications.

MAJOR ACCOMPLISHMENTS

Accomplishments in the pavements area included construction and testing of an advanced rolling weight deflectometer capable of providing continuous data on pavement conditions and load carrying capacity. This equipment represents the next generation of pavement evaluation tools and will provide increased reliability and reduced times for airfield evaluation teams currently using spot check methods. Advanced materials and techniques for emergency pavement repairs were developed and tested along with validation tests on fiberglassmat anchoring systems. Studies were accomplished on the use of in-theater materials for global repair capability, and on new optical sensor technologies for advanced pavement evaluation capability.

AIR BASE PAVEMENTS AND FACILITIES

Subthrust	FY95	FY96	FY97	FY98	FY99	FY00	FY01	FY02+
Pavements	Pavement Evaluation Technologies							
	Transportable Surface Technologies							
	Contingency Airfield Creation, Repair & Deicing							
	Improved Quality Control							
Facilities	Advanced Pavement Materials							
	Contingency Airfield Database Management							
	Pavements for Superheavy Transport							
	Airmobile Shelters							
	Bare Base Hardening							
	CCD Modeling							
	Advanced Material for Deployable Sys							
	CHEM/BIO Processing for Shelters							
	Stealth Shelter Concepts							
	Munition & POL Storage for Bare Base							
	Advanced Shelters							

In the facilities area, extensive testing was conducted to evaluate external composite reinforcement of concrete elements. Increases in load carrying capacities of 200-400 percent were realized. Joint full scale explosive tests were successfully conducted with the Israelis demonstrating the potential of using this technology for retrofitting existing structures to increase survivability to SCUD missiles. In the airmobile shelter research program, pultruded fiberglass panels were designed and tested for a modular hardwall shelter to be tested in early FY96. Studies were completed on composite lightweight materials, and dynamic laboratory tests were conducted on unique honeycomb designs.

CHANGES FROM LAST YEAR

The FY96 Pavements and Facilities Thrust Area was formulated by combining last year's Airbase Survivability Thrust and portions of the Airbase Operability Thrust. This change was accomplished to accommodate reorganization of the Airbase Systems Branch due to downsizing. No major changes in investment strategy have been made with R & D investments still focused on the mobility mission.

MILESTONES

Improved pavement evaluation tools will be provided by completion of the Advanced Pavement System Analyzer program in early FY96. Portable ground penetrating radar to evaluate pavements at deployment locations will be completed by FY98. Transportable lightweight matting for aircraft parking and advanced pavement repair materials and processes can be developed by FY99.

Milestones for a new family of portable shelters include component testing and full scale advanced technology demonstrations for prototype hardwall and softwall shelters in FY96. Studies and testing of lightweight ballistic panels have proven external expedient hardening is the most cost effective protection for bare base shelters and parked aircraft. Development of lightweight systems used with in-theater materials will be completed by FY98 to provide this protection. The capability to enter/egress/process in a chemical/biological environment will be added to the shelters by FY02. Advanced concepts for bare base storage of POL and munitions will be completed by FY00.

These milestones will greatly enhance current bare base capabilities and provide the Air Force with new technologies to eliminate current readiness shortfalls.

THRUST 3: ENVIRONMENTAL COMPLIANCE

USER NEEDS

The Environmental Compliance program has been adjusted to align its projects with the high priority user needs specified in the ESOH TPIPT Technology Needs Survey and address new and future regulatory requirements and tri-service needs under Project Reliance. Major users include AF/CE, ACC, AMC, AETC, AFSPACECOM, and AFMC Air Logistics and Product Centers. In order to address these needs and requirements, the Environmental Compliance program has been reorganized into four subthrusters or Focused Technology Areas (FTAs):

- **Hazardous Waste Technologies.** In this area Compliance programs address needs for solid rocket motor disposal, wastewater treatment, metal removal from waste products, oil-water emulsion and AFFF treatment, reduction of paint stripping wastes, and industrial sensor development.
- **Alternate Processes and Materials.** Environmental Compliance programs address needs to develop new deicers, eliminate hazardous materials, reduce heavy metal wastes through acceptable alternative processes and materials, and recycle and reuse critical process and aircraft fluids.
- **Air Pollution Control.** Environmental Compliance programs address needs to reduce NO_x in both high temperature and low-temperature environments, reduce VOC emissions, and control inorganic emissions including mercury, particulates, CO, and other emissions from repainting operations.
- **Atmospheric Emission Risk Assessment.** Environmental Compliance programs address needs to understand the atmospheric chemistry of volatile new materials, better characterize rocket plumes and validate plume dispersion and reaction models, identify low-cost highly sensitive monitoring technologies, and characterize JP-8 emissions.

GOALS

- Identify novel approaches to treat oil-water emulsions from aqueous degreasers that contain hazardous materials (FY95), and demonstrate at the bench scale (FY98)
- Identify a chemical/physical or biological treatment for AFFF (FY95) and construct and demonstrate at several locations a transportable treatment system (FY96-FY97).
- Optimize (FY95) and demonstrate (FY95-96) a skid-mounted sodium sulfate-ferrous sulfite sludge treatment pilot plant.
- Demonstrate cost effective treatment technologies for the treatment/recycle of metal and halogen contaminated sludges at the bench (FY97) and pilot plant (FY00) scale.
- Identify low-cost treatment/mitigation technologies to reduce cadmium waste water generation from aircraft turbine engine cleaning operations (FY99).
- Develop cost effective technologies to reduce paint stripping wastes from current and future paint stripping operations (FY98) and demonstrate in a pilot plant scale (FY00).
- Demonstrate the cryogenic removal and destruction of hazard class 1.1 rocket propellant (FY95) and class 1.3 Minuteman propellant (FY96).
- Establish a novel reactor treatment program (FY95) to develop efficient, low-cost liquid energetic destruction/conversion technologies (FY97) and complex chemical waste destruction/conversion technologies (FY00).
- Synthesize and demonstrate new ice inhibiting compounds for deicing applications (FY96).
- Develop and demonstrate non-chromate conversion coatings for IVD aluminum (FY97).
- Construct and validate a spray casting pilot plant with the National Defense Center for Environmental Excellence (NDCEE), as an alternative to electroplating (FY96).

ENVIRONMENTAL COMPLIANCE

Subthrust	FY95	FY96	FY97	FY98	FY99	FY00	FY01	FY02+
Hazardous Waste Technologies	AFPP Trmt Tech							
	LRM Trmt & Disposal							
	Advanced Chemical Reactor Program							
	Advanced Energetics Treatment Program							
	Paint Stripping Waste Reduction							
	Advanced Oil/Water/Emulsion Separation Technology							
Alternative Processes & Materials	Heavy Metal Waste Water Treatment							
	Environ Comp Deicers						Hazardous Materials Elimination Program	
							Heavy Metals Elimination Program	
							Chemical Tank Recycle & Rejuvenation	
Air Pollution Control	High Temperature NOx Control							
	Low Temperature NOx Control							
	Organic Emission Control Technologies							
Atmospheric Emissions Risk Assessment	Inorganic Emission Control Technologies							
	Environ Impact/Compliance Modeling							
	Space Launch Risk Assessment							
	Atmospheric Studies of Volatile New Materials							

- Develop technologies for the ion vapor deposition (IVD) of heavy metals (FY98).
- Demonstrate cost-effective technologies to reclaim and recertify hydraulic fluid (FY96).
- Develop effective treatment/rejuvenation technologies for aqueous degreasers and their associated hazardous waste (FY98) and demonstrate at the pilot plant scale (FY00).
- Develop and demonstrate multiple NOx control technologies for various applications including turbine engines, jet engine test cells (JETCs), and aerospace ground equipment (AGE). Demonstrate sub-scale cold plasma and sorbent/catalyst NOx control for JETCs (FY96) and demonstrate AGE NOx control technologies (FY97).
- Demonstrate effective, efficient mercury vapor recovery technologies (FY97).
- Demonstrate regenerable catalysts for VOC recovery/control (FY98).
- Demonstrate recirculating paint booth technology for VOC control (FY98).
- Develop and validate the emissions reduction planning model (FY97).
- Demonstrate an advanced hydrazine monitor for part per billion detection limits (FY96-97).
- Provide SMC data to refine rocket plume dispersion models (FY96), characterize catastrophic abort phenomena (FY97), and validate toxic risk assessment models (FY99).

MAJOR ACCOMPLISHMENTS

The Large Rocket Motor Demil/Disposal Program neared fruition with the completion and initial testing of several pilot plant demonstration units. A continuous flow bioreactor system for Ammonium Perchlorate (AP) treatment was installed and preliminary testing conducted at Tyndall AFB. This research quality system, consisting of anaerobic and aerobic reactor sections, establishes a test bed for obtaining full-scale economic and process data for essentially any biodegradation process. Propellant removal and treatment demonstration units were installed at the Thiokol Corporation's Wasatch facility near Brigham City, Utah. The liquid nitrogen propellant washout system advanced the state-of-the-art for high pressure cryogenic processes (30,000 psi) and will enable neat propellant and, potentially,

rocket motor case recovery. The associated hydrothermal treatment unit that will destroy hydrolyzed propellant, is the largest unit of this type capable of processing an energetic slurry.

Environmental Compliance Division was awarded the prestigious R & D 100 Award for its part in the development of a modification to the electroless nickel process that allows the plating bath to be perpetually regenerated thereby eliminating the generation of hazardous wastes.

A demonstration of a biofilter for VOC control was successfully conducted at Tyndall AFB on a slip stream from an actual aircraft paint spray booth. In separate laboratory-scale tests, the feasibility of using regenerable catalysts for VOC control was confirmed. A cold plasma reactor was designed and fabricated to study the low-temperature reaction kinetics and characterize products from VOC, NOx and other air contaminant reactions. A full-scale demonstration of a sorbent/catalyst for NOx and CO control on diesel engines was conducted at McClellan AFB. Also for McClellan AFB, a full-scale NOx control demonstration system was designed and is being installed on a jet engine test cell.

CHANGES FROM LAST YEAR

Significant reduction in JOCG and SERDP funding was offset by an increase in both the 6.2 and 6.3 budget for compliance R & D. Program changes, in addition to the major restructuring of the previous year, were made to address additional ESOH needs, to anticipate technology requirements for future needs, and to place additional emphasis on air pollution control technologies. The congressionally directed plus-up for the Spray Casting program (\$5 million in PE603723F for FY94) was actually received in FY95 and is being executed through a collaborative effort with the National Defense Center for Environmental Excellence (NDCEE). In order to better address user needs and establish needs and establish a more representative program, technology focus areas were restructured into four areas from six for the previous year. These areas are: Hazardous Waste Technologies, Alternate Processes and Materials, Air Pollution Control, and Atmospheric Emission Risk Assessment.

MILESTONES

The development and demonstration of air emission control technologies is critical to meeting current and anticipated requirements for both stationary and mobile sources. Long-term ability to meet these requirements depends specifically on the success of the catalyst/sorbent technology to be tested in AGE in FY95 and in a full-scale JETC demonstration in FY96, and on the effectiveness of low-temperature plasma technology, high temperature electro-catalysts, and regenerable catalysts for VOC removal and oxidation. The characterization of criteria and hazardous air pollutants from JP-8 combustion in turbine engines and other mobile and stationary sources (FY95-96) will help define the extent to which these mitigation technologies must be employed. Continued understanding of the atmospheric chemistry of our emissions, the incorporation of this data into current models, and the validation of dispersion/diffusion/reaction models, are critical

steps in establishing acceptable Air Base emissions compliance models.

The design and construction of a spray casting demonstration unit at NDCEE will not only provide an alternative method to some plating operations but will become a test bed for many material and process trade studies for Air Force and other DOD unique parts. Similarly, establishing an in-house reactor technology capability will provide methods to rapidly evaluate the effectiveness of new catalysts and novel reactor technologies to treat new materials, hazardous aqueous and gaseous effluents, and energetic compounds. The demonstration tests on the cryogenic propellant removal and treatment systems (FY95-96) will provide data for a safe, environmentally acceptable way to recover rocket motor components/materials and dispose of obsolete or unserviceable assets. A follow-on program, partially supported by the Environmental Security Technology Certification Program (ESTCP), will provide data that may enable these technologies to be used in the Minuteman III Propulsion Replacement Program.

THRUST 4: SITE REMEDIATION

USER NEEDS

The ESOH TPIPT Technology Needs Survey identifies a wide range of requirements in the area of site remediation. Since the Air Force is the lead service for fuels and solvents cleanup under Project Reliance, the site remediation program principally addresses these particular needs. Indeed, the detection and cleanup of the chlorinated solvents (also referred to as Dense Non-Aqueous Phase Liquids, or DNAPLs) were the two high priority needs in the cleanup pillar. The Site Remediation addresses these needs under the following four subthrusts or Focused Technology Areas (FTAs):

- **Bioremediation Technologies.** This area aims to develop *in situ* bioremediation technologies as simple, inexpensive means of removing chlorinated solvents and fuels from both soil and groundwater.
- **Physical/Chemical Treatment Technologies.** For those sites where bioremediation is ineffective or too slow, P/C technologies may be required to effectively address these particular remediation needs.
- **Site Characterization/Monitoring.** This area addresses the need for improved technologies and devices to characterize/monitor sites for contamination. This is a very important area, comprising 20 to 50 percent of total site cleanup costs.
- **Contaminant Fate and Transport.** This FTA addresses user needs for models to track the movement of contaminants in soil and water, to predict the interaction of contaminants with the environment, and to provide risk assessment with respect to human health.

GOALS

- Demonstrate technology for *in situ* treatment of DNAPLs/chlorinated solvents in all soil types (FY99).
- Develop technology for *in situ* bioremediation of chlorinated solvent contaminated soil (FY00).

- Demonstrate technologies for treatment of dissolved and residual chlorinated solvents in groundwater (FY97).
- Demonstrate technologies for treatment of dissolved and residual fuel in groundwater (FY97).
- Develop bioremediation technology for hydrazine propellant spills (FY99).
- Develop *in situ*, real time monitoring technology to enhance/optimize remedial actions (FY98).
- Develop nonintrusive/noninvasive technologies to characterize DNAPLs in the subsurface (FY00).
- Develop risk based remediation model for waste site decision making (FY99).
- Develop a 3-D, multiphase, DNAPL transport model (FY00).
- Develop sound scientific foundation for selection of natural attenuation as a remedial action alternative at hydrocarbon contaminated sites (FY97).

MAJOR ACCOMPLISHMENTS

The site remediation thrust of AL/EQ develops technologies to be utilized in the clean-up of contaminants at Air Force locations worldwide. The site remediation thrust of AL/EQ develops technologies to be utilized in the clean-up of contaminants at Air Force locations worldwide. The technologies can be utilized to remediate, characterize, or monitor these pollutants whether they were released to the environment 50 years ago or yesterday (or even in the future).

AL/EQ has developed various bioremediation technologies, which can clean up fuels and certain solvents from contaminated soil and groundwater. Bioremediation offers significant cost savings over other treatment technologies, since microorganisms are employed to do the work rather than expensive chemicals and energy.

For example, AL/EQ spearheaded and optimized the development of bioventing, an aerobic treatment technology of petroleum hydrocarbon-contaminated soils. The cost of remediation using this technology

SITE REMEDIATION

Subthrust	FY95	FY96	FY97	FY98	FY99	FY00	FY01	FY02+
Bioremediation Technologies								
Physical/Chemical Treatment Systems								
Fate & Transport of Subsurface Contaminants								
Characterization/Monitor Technologies								

has been documented at \$5-\$15/cubic yard versus \$30/cubic yard for using soil venting technology and over \$100/cubic yard for incineration or landfill disposal. The total cost savings to the Air Force is conservatively estimated at \$187M. Bioventing technology development efforts at Tyndall AFB, FL, showed that biodegradation rates are unaffected by nutrient and moisture addition, but correlated well with *in situ* soil temperatures. Bioventing, in conjunction with soil warming techniques, is being tested in the sub-arctic environment at Eielson AFB, AK. Results to date suggest that a soil warming system, operated in conjunction with bioventing, is a cost effective method for remediating fuel-contaminated areas in cold climates. This project concluded in FY94 with a complete economic analysis of these techniques.

AL/EQ is also exploring anaerobic biodegradation of tetrachloroethylene, better known by the trade name perchloroethylene (PCE). Researchers previously developed a bacterial culture, which dechlorinates high concentrations of PCE and other chlorinated ethenes to ethane (ETH), representing complete detoxification. A site has been chosen at Fallon NAS, NV, where knowledge from the anaerobic study will be applied *in-situ* to remediation of PCE. Natural attenuation will serve as a comparative study.

A Cooperative Research and Development Agreement (CRDA) with Dow Chemical Corporation was created to demonstrate a granular activated carbon fluidized-bed bioreactor to treat chlorobenzene-contaminated groundwater. The bioreactor's performance has shown 99 percent reduction of chlorobenzene concentrations.

The demonstration of an innovative technology for remediating groundwater contaminated with jet fuel and chlorinated solvents took place at Robins AFB, GA. Groundwater at this site is contaminated with significant levels of dichloroethylene, trichloroethylene, toluene, benzene, chlorobenzene and dichlorobenzene. The treatment system consisted of a fluidized bed bioreactor (FBR), an air stripper and a gas phase bioreactor. The FBR effectively treated groundwater with only very low levels of TCE and dichlorobenzene detected in the treated effluent. All other compounds were treated to below detection limits. The Air Force now has a water treatment technology applicable to both site remediation and industrial effluent treatment that

provides cost-effective and complete destruction of fuel and chlorinated solvents.

Studies have shown that alternate electron acceptors (e.g., nitrate) in the place of oxygen, can be utilized by microorganisms to enhance biodegradation. In a joint project with the US EPA Kerr Environmental Research Laboratory, we are demonstrating enhanced anaerobic *in situ* bioremediation of jet fuels at Eglin AFB, FL. The demonstration will further quantitatively assess the rate and extent of bioremediation of fuel components when nitrate is injected. Results indicate denitrification to be occurring along with reduction in contaminants. This field study is due to be completed in May FY95.

A CRDA was signed with Unisys Corporation, North Dakota State University, and a small business, Dakota Technologies, Inc., to commercialize our tunable laser spectrometer. This project is part of Advanced Research Projects Agency (ARPA) Technology Reinvestment Project (TRP) which is investing millions of dollars to develop new technologies for exciting uses. This program emphasizes partnership between the U. S. military and civilian industry, resulting in advanced military systems and competitive commercial products. A transportable, tunable laser spectrometer with fiber optic probes continued to be demonstrated. The technology was upgraded and capabilities were expanded from monitoring groundwater for fuel components to include solvent detection capabilities. In addition, a method was developed to measure hexavalent chromium in a collected groundwater sample by colorimetric reaction, which is then analyzed by the laser spectrometer.

Site characterization and analysis penetrometer technology was made available for transition to HSC/YAQ to perform standard geophysical and fuel contamination characterization. A joint AL/EQ and AFCEE effort is demonstrating the technology at multiple Air Force installations to further validate the system performance capabilities and to determine amenability of contaminated sites to natural attenuation (intrinsic bioremediation) processes.

The tunable laser/cone penetrometer was demonstrated through the EPA Superfund Innovative Technology Evaluation (SITE) program and a US/German Environmental Data Exchange Agreement.

The Environics Directorate established the Groundwater Remediation Field Laboratory (GRFL) at Dover AFB, DE. Funded by the Strategic Environmental Research and Development Program (SERDP), the GRFL is designed for technology demonstrations, as well as fate and transport studies, which require the controlled release of contaminants into the soil or groundwater. The efficiency of a remediation technology can be fully evaluated only when the amount of contaminant initially present is known. The GRFL is the only facility in the United States where such studies can be performed.

Funnel-and-gate remediation systems were developed for an FY97 field demonstration. In a funnel-and-gate system, sheet piling is driven into the path of a contaminant plume, forming a funnel which directs the groundwater through an engineered reactive area, the gate. Remediated groundwater exits the downgradient side of the gate. Potential gate technologies, such as metallic iron, immobilized enzymes, and hydrogen peroxide were simultaneously being studied as treatments for chlorinated solvents.

Steam was utilized in a field demonstration to remove a trichloroethylene source contaminating groundwater at Hill AFB, UT. Lessons learned will be used to further refine the process and develop a commercial technology for FY96.

Side-by-side demonstrations of eight technologies designed to enhance the effectiveness of pump-and-treat systems were initiated at Hill AFB, UT under the Enhanced Source Removal Demonstration Project. The objective of this effort is to directly compare the effectiveness of these treatments (co-solvent flushing, surfactants, steam injection, and air sparging) under nearly identical field conditions. The results of these demonstrations will be used to produce guidance documents for applying these processes to remediate contaminated groundwater. The guidance will address the entire remediation effort, including site characterization and supporting laboratory work required to achieve the maximum benefit from the remediation technologies included in the study.

A field demonstration of two different radio frequency (RF) heating designs was concluded at Kelly AFB, TX. The RF treatment system removed various volatile and semi-volatile contaminants from the soil; however, no definite conclusions can be drawn regarding the relative performance and cost-effectiveness of this technology against competing

ones. Any further development of this technology will probably be left up to the private sector.

Advances in the subsurface contaminant fate and transport studies can save the Air Force millions of dollars in site characterization through optimization of the data collection process and in actual remediation by providing minimal treatment options when risk assessments support such decisions.

A field study in cooperation with the Tennessee Valley Authority will demonstrate natural attenuation of a residual hydrocarbon source. Key environmental indicators of natural attenuation will be identified. Results will justify recommending natural attenuation as a remediation alternative for USAF sites with hydrocarbon contaminated groundwater. Savings will be enormous if regulators accept the concept.

Development is progressing on a Risk Based Remediation model to assist remedial project managers in decision making based on a risk-based approach. This model is fundamental in maintaining a common sense approach to site clean-ups where remediation costs are driven by unfounded criteria or lack of understanding of actual environmental impact. Quantification of risk is essential to achieving lower clean-up costs resulting from remedial action overkill.

Technology development continued on identifying retardation factors of selected energetic materials. Data obtained contributed to understanding the environmental fate of energetic materials and provides a proactive approach to AF environmental problems. This will simplify the problem of selecting remediating techniques when those materials enter the environment.

CHANGES FROM LAST YEAR

This year's program reflects a shift in emphasis toward meeting the two high priority user needs in site remediation: (1) detection/monitoring of DNAPLs/chlorinated solvents and (2) remediation of DNAPLs/chlorinated solvents.

Two very important technologies/processes that were spearheaded by the site remediation program have now/are now being implemented at numerous Air Force bases. These are bioventing (for cleanup of fuels in soils) and intrinsic remediation (for cleanup of fuels in groundwater). Both of these technologies/methods are very simple, cheap, and, in most cases, effective means of cleaning up fuels in

the subsurface. Therefore, the site remediation program is now much more heavily focused on the DNAPL/chlorinated solvent problem. .

MILESTONES

An economic analysis will be completed in FY95 to determine the cost effectiveness of applying bioventing with soil warming for bioremediation in a subarctic environment. Pulsing of injected air and oxygen will be demonstrated to determine the effect on biodegradation rates during the fourth quarter of FY94. A draft summary of bioventing and the data obtained will have been published by the Environics Directorate of Armstrong Laboratory in FY95 under the title, "Bioventing Principles-of-Practice Manual." The final report, including the economic analysis, will be published in FY95.

Under our CRDA, Dow Corp. will provide a final report in FY95, yielding a detailed technical description of the field performance and a cost comparison between the bioreactor and the existing air stripper/thermal destruction treatment technology.

Laboratory studies for the nitrate-based bioremediation project were conducted to assess process feasibility under denitrifying conditions. The site has been characterized, groundwater modeled and the bioremediation technology designed and installed. Startup of nitrate addition began in April 1994 and is scheduled to end in FY95. Results from the *in situ* field demonstration will determine the efficacy of using nitrate-based bioremediation by quantifying JP-4 removal rates, assessing environmental and ecological impacts and determining the cost effectiveness. A final report on technology costs applicability and design parameters will then be published in FY96.

Reductive dechlorination of chlorinated ethenes has been successfully demonstrated in the laboratory using butyrate and formate for the reductive dechlorination of tetrachloroethylene. These reducing agents will be evaluated in comparative studies to determine the best agent to use in the field. The selected substrate will then be used in a continuous flow reactor study. The technology from this effort will have application at any Air Force site contaminated with highly chlorinated solvents.

The ultimate objective in the area of site characterization and monitoring is to obtain a sensor,

site characterization, and monitoring technologies that will measure fuel and solvent contamination to regulatory limits. Once this is accomplished, user and regulatory acceptance must be obtained. The Environmental Systems Management Analysis and Reporting Network (E-SMART) makes use of "smart" sensors and actuators to provide installation-wide environmental management and process control. Partners in the E-SMART development team include General Atomics, Photonic Sensor Systems, Georgia Tech Research Center, and the Science and Engineering Analysis Corporation. E-SMART was submitted to the ARPA Technology Reinvestment Project (TRP) and awarded \$2.7M. Matching funds from partner organizations brings the total value of the project to \$5.4M.

Steam-enhanced extraction extends source removal technology to below the water table, with a milestone of an operational process by FY96. This process is being demonstrated under a Phase II SBIR at a solvent-contaminated site at Hill AFB, UT.

Funnel-and-gate treatment systems under development will be evaluated, and one chosen by mid-FY96 for the field demonstration in FY97. A cost model was developed to accurately compare funnel-and-gate systems with conventional pump-and-treat systems. A hydrodynamic model will be completed in early FY96 to assist in installing funnel-and-gate systems.

Through the Dense Solvent Remediation project, an expert panel was established to identify the most promising technologies for the remediation of Dense Non-Aqueous Phase Liquid (DNAPL) sources in aquifers. Currently there is no effective technology which will remove or treat bulk solvent material that sinks to the bottom of aquifers or is trapped in the soil interstices ("ganglia"). Plans are now being made to test the most promising technologies under controlled laboratory conditions. Other activities within this project include integrating DNAPL source location efforts with these remediation technologies.

A field scale controlled contaminant release, the Natural Attenuation Study, will transition from lab to field in spring FY95. The key environmental indicators of natural attenuation at hydrocarbon contaminated sites will be identified and provide the scientific foundation for selection and regulatory approval of natural attenuation as a remedial action alternative. This knowledge will transition to the FY96 program Natural Attenuation Technology

Demonstration, to be performed at an actual contaminated hydrocarbon site. Demonstrating the concept will rely on the key indicators identified in the 6.2 research effort and lend credibility to natural attenuation as a viable remedial action.

An FY96 physical model study will research the fate and transport of DNAPLs. Quantitative

measurements will be made and data sets developed for eventual use in a 3-D, multiphase, DNAPL transport model. The model selected will be enhanced to appropriately describe the model and data collected. The result will be a 3-D, multiphase DNAPL transport model available to remediation project managers (RPMs) for use in decision making.

GLOSSARY

ACC	Air Combat Command	GCATT	Gulf Coast Alliance for
AETC	Air Education and Training		Technology Transfer
	Command	GRFL	Groundwater Remediation Field
AFCEE	Air Force Center for		Laboratory
	Environmental Excellence	HAP	Hazardous Air Pollutant
AFCEA	Air Force Civil Engineering	HSC	Human Systems Center
	Support Agency	HVAC	Heating, Ventilation and Air
AFFF	Aqueous Film Forming Foam		Conditioning
AFMC	Air Force Materiel Command	IEA	Information Exchange Agreement
AFOSR	Air Force Office of Scientific	IVD	Ion Vapor Deposition
	Research	JETC	Jet Engine Test Cell
AFSPACECOM	Air Force Space Command	JOCG	Joint Ordnance Commanders
AGE	Aerospace Ground Equipment		Group
AL	Armstrong Laboratory	MOU	Memorandum of Understanding
AL/EQ	Armstrong Laboratory's	MSN	Mission Need Statement
	Environics Directorate	NOx	Oxides of Nitrogen
AMC	Air Mobility Command	NRL	Naval Research Laboratory
ARPA	Advanced Research Projects	ORD	Operational Requirements
	Agency		Document
CCD	Camouflage, Concealment, and	PCE	Perchloroethylene
	Deception	POL	Petroleum, Oil, and Lubricants
CE	Civil Engineering	R&D	Research and Development
CRDA	Cooperative Research and	RF	Radiofrequency
	Development Agreement	RPM	Remediation Project Manager
D/NETDP	DOD/National Environmental	S&T	Science and Technology
	Technology Demonstration	SBIR	Small Business Innovation
	Program		Research
DEA	Data Exchange Agreement	SCBA	Self-Contained Breathing
DERA	Defense Environmental		Apparatus
	Restoration Account	SERDP	Strategic Environmental
DNALP	Dense Non-Aqueous Phase		Research and Development
	Liquids		Program
DOD	Department of Defense	SITE	Superfund Innovative Technology
E-SMART	Environmental Systems		Evaluation
	Management Analysis and	SMC	Space and Missile Center
	Reporting Network	SON	Statement of Need
EPD	Energy Policy Directive	TAP	Technology Area Plan
EQ	Environmental Quality	TCE	Trichloroethylene
ESOH	Environment, Safety, and	TPIPT	Technical Planning Integrated
	Occupational Health		Product Team
ESTCP	Environmental Security	TRP	Technology Reinvestment Plan
	Technology Certification	VOC	Volatile Organic Compound
	Program	WL	Wright Laboratory
ETH	Ethane	WL/FIVC	Wright Laboratory's Flight
FBR	Fluidized Bed Bioreactor		Dynamics Directorate, Airbase
FTA	Focused Technology Area		Systems Branch

Technology Master Process Overview

Part of the Air Force Materiel Command's (AFMC) mission deals with maintaining technological superiority for the United States Air Force by:

- Discovering and developing leading edge technologies
- Transitioning mature technologies to system developers and maintainers
- Inserting fully developed technologies into our weapon systems and supporting infrastructure, and
- Transferring dual-use technologies to improve economic competitiveness

To ensure this mission is effectively accomplished in a disciplined, structured manner, AFMC has implemented the Technology Master Process (TMP). The TMP is AFMC's vehicle for planning and executing an end-to-end technology program on an annual basis.

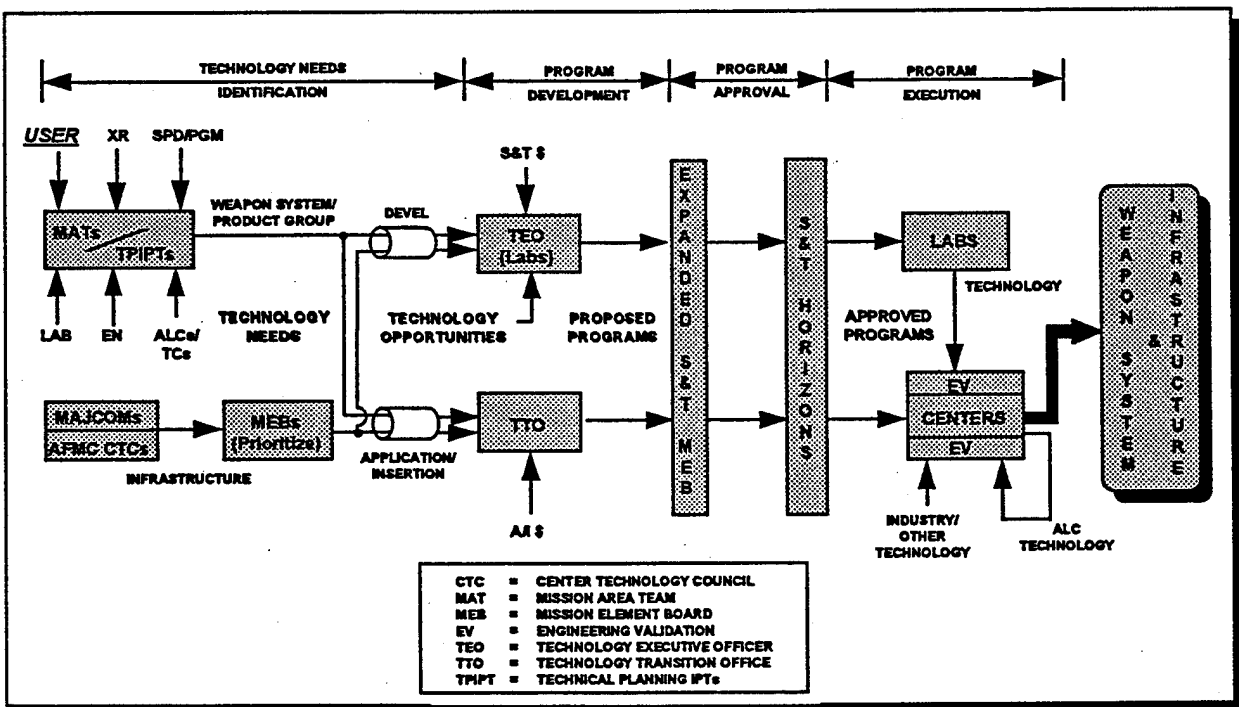


Figure 1 - Technology Master Process

The TMP has four distinct phases, as shown in Figure 1:

- **Phase 1, Technology Needs Identification**—Collects customer-provided technology needs associated with both weapon systems/product groups (via TPIPTs) and supporting infrastructure (via CTCs), prioritizes those needs, and categorizes them according to the need to develop new technology or apply/insert emerging or existing

technology. Weapon system-related needs are derived in a strategies-to-task framework via the user-driven Mission Area Planning process.

- **Phase 2, Program Development**--Formulates a portfolio of dollar constrained projects to meet customer-identified needs from Phase 1. The Technology Executive Officer (TEO), with the laboratories, develops a set of projects for those needs requiring development of new technology, while the Technology Transition Office (TTO) orchestrates development of a project portfolio for those needs which can be met by the application/insertion of emerging or existing technology.
- **Phase 3, Program Approval**--Reviews the proposed project portfolio with the customer base via an Expanded S&T Mission Element Board and, later, the AFMC Corporate Board via S&T HORIZONS. The primary products of Phase 3 are recommended submissions to the POM/BES for S&T budget and for the various technology application/insertion program budgets.
- **Phase 4, Program Execution**--Executes the approved S&T program and technology application/insertion program within the constraints of the Congressional budget and budget direction from higher headquarters. The products of Phase 4 are validated technologies that satisfy customer weapon system and infrastructure deficiencies.

TMP Implementation Status

The Technology Master Process is in its first full year of implementation. AFMC formally initiated this process at the beginning of FY94 following a detailed process development phase. During the FY95 cycle, AFMC will use the TMP to guide the selection of specific technology projects to be included in the Science and Technology FY98 POM and related President's Budgets.

Additional Information

Additional information on the Technology Master Process is available from HQ AFMC/STP, DSN 787-7850, (513) 257-7850.

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